The Importance of Transmit Arrays for Capturing Central SNR at Ultra-High Fields (UHF)

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Primary Aim:

The primary focus of this work is to highlight the importance of transmit arrays (used as additional receivers) for capturing central SNR at Ultra High Fields (UHF). Since the number of available receiver channels in typical UHF systems (≥ 7T) is unfortunately still often more limited than clinical 3T systems, one question to ask is: *If we had additional receive channels available, would it be advantageous to use transceivers or rather keep the focus on maximizing the number of close-fitting receiver elements to increase central SNR?*

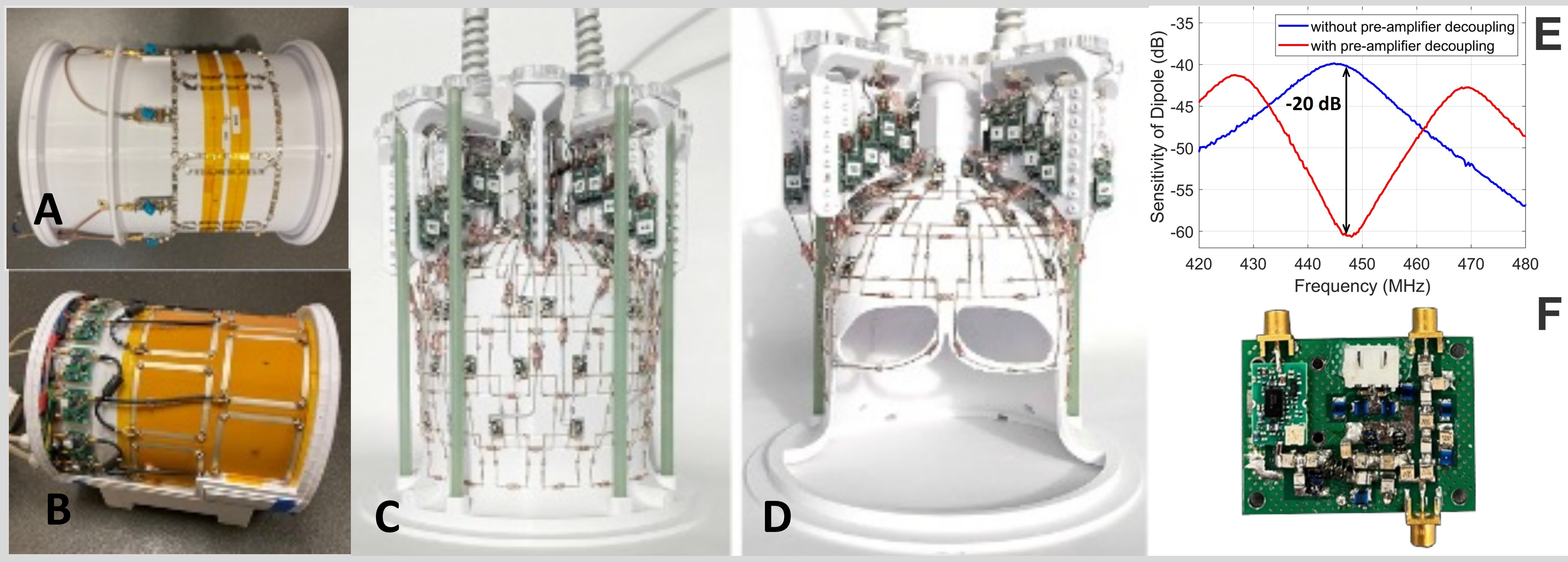

Fig. 1: (A) Shows the 8-ch overlapped loop (12x12cm^2) and (B) 16-ch dual row SD (10x10cm^2) loop transmitters. (C, D) shows the 64-ch 447MHz SD receiver used for all experiments. (E) Resulting preamplifier decoupling achieved when the miniature T/R switch with integrated preamplifier (F) was paired with the transmit element.

Methods:

In order to help us improve SNR and to evaluate the limits of Ultimate Intrinsic Signal to Noise Ratio (UiSNR) at UHF, we recently expanded the receive chain on our Siemens 10.5T system from 64 to 128 channels. This upgrade paired with 16 channel parallel transmit capability and the development of miniature local Transmit/Receive (T/R) switches with integrated preamplifiers has provided the opportunity for us to fully evaluate the achievable gains in SNR when utilizing *ALL* of the transmitter and receiver array elements as receivers. We first evaluated the cumulative SNR from a 56 channel receive-only array paired with an 8 channel geometrically-decoupled transmit array used in both transmit-only and T/R modes, then a similar experiment was conducted with a 64 channel receive-only array with a 16 channel Self-Decoupled (SD) transmit array resulting in coil assembly combinations of 8Tx/56Rx vs 8Tx/64Rx & 16Tx/64Rx vs 16Tx/80Rx respectively. All phantom testing was conducted using a lightbulb-shaped former filled with a human tissue-mimicking PVP solution (Ɛr: 47.2, σ: 0.65 S/m) at 447 MHz, the ^{1}H Larmor frequency at 10.5 T.

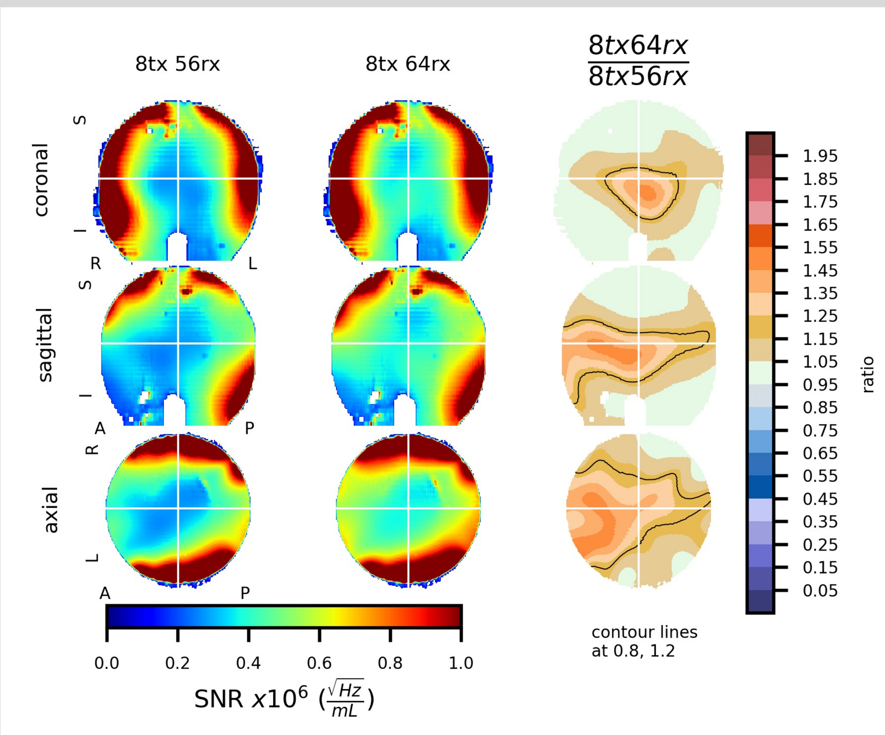

Fig. 2: SNR with a 56 Rx receive-only array versus 56Rx+8 Tx/Rx combined array.

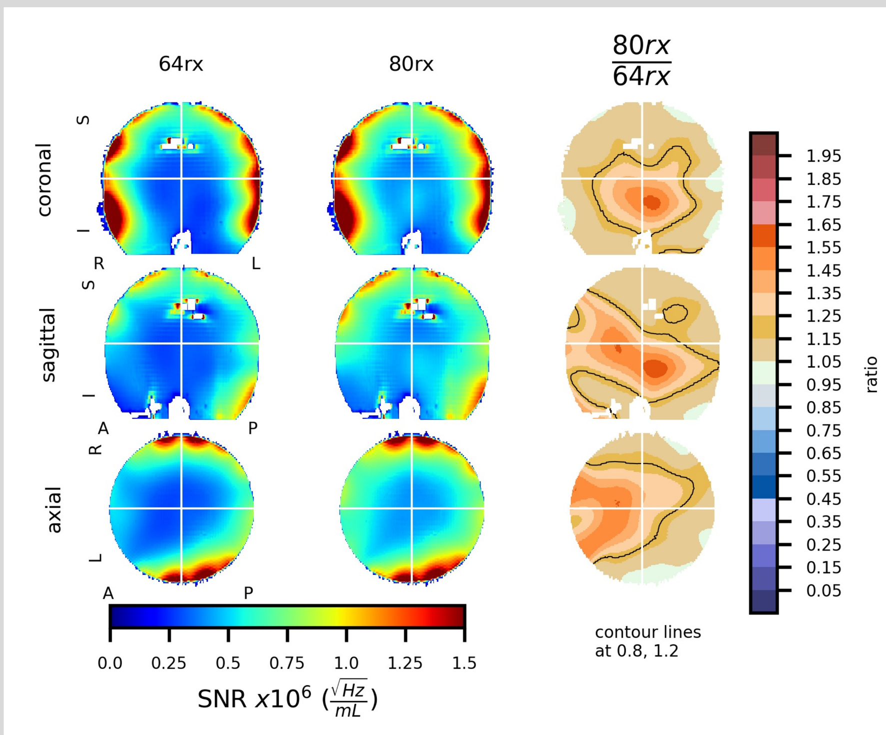

Fig. 3: SNR with the 64 Rx receive array and 80Rx (64Rx+16 channel SD dual loop Tx/Rx).

Results:

The transmit array element(s) in both cases (8 T/R & 16 T/R) supported optimized subject-specific B_1^+ volume-like shims during transmission and were used as additional independent receive elements during acquisition. The combined 8Tx/64Rx overlapped loop coil array showed up to ~40% increased central SNR gains (Fig. 2). The recent expansion of the number of receivers from 64 to 128 channels allowed us to fully explore a true 64 channel receive-only array in combination with a dual row 16 channel non-overlapped SD array operating in a T/R mode. The resulting 16Tx/80Rx array showed up to ~40% improved central SNR improvements as well as in the regions around the eyes where the 64 channel receive-only array alone had fewer loops (Fig. 3). The miniaturization and integration of T/R switches (see Fig 1F) which employed preamplifier decoupling techniques aided in coil isolation during the receive acquisition and significantly improved the overall workflow, as we no longer needed external interface hardware. Cumulative gains from the proposed transceiver – receiver array combinations were able to capture upwards of 50% more SNR for central slices.

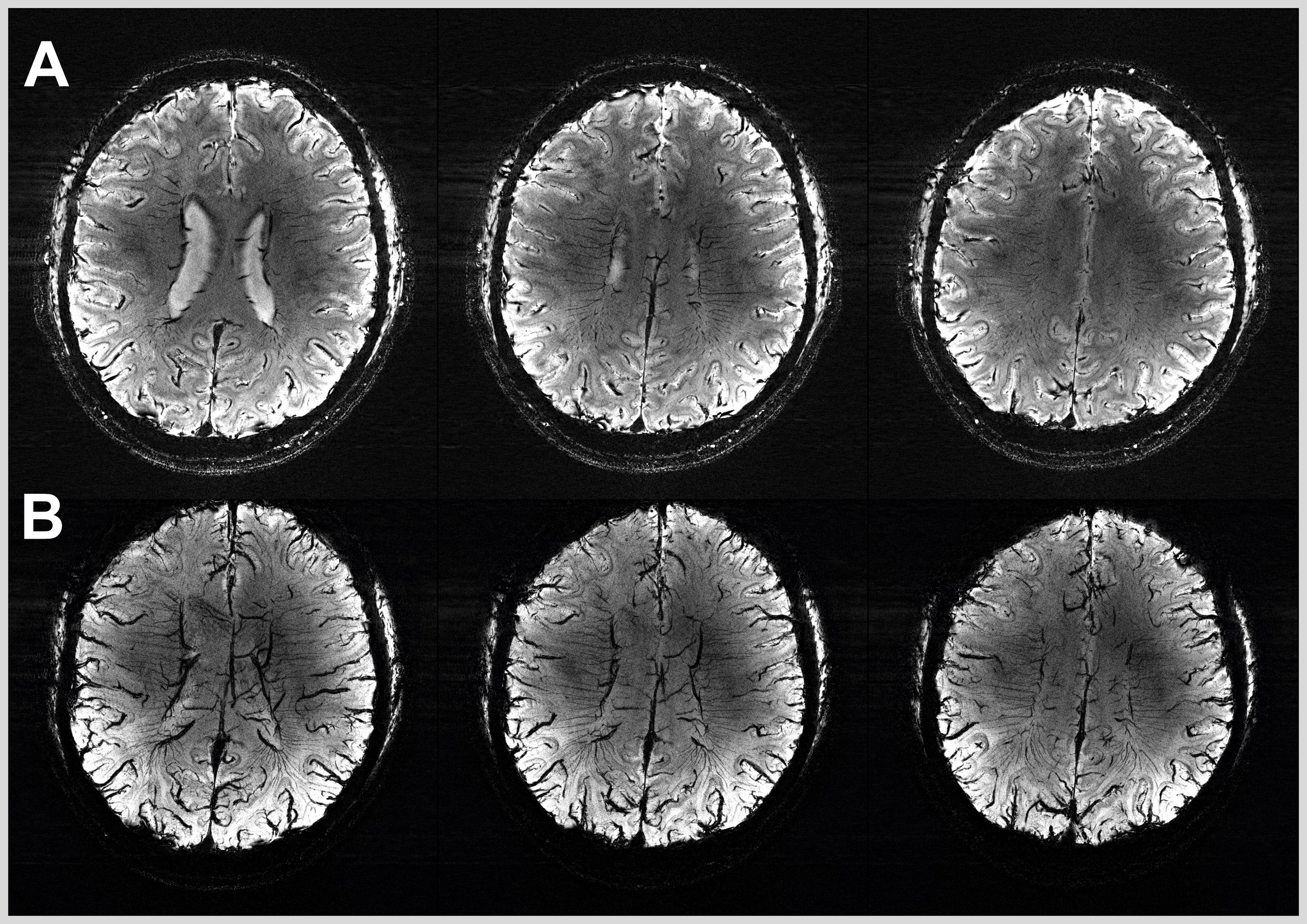

Fig. 4: (A) Example susceptibility weighted imaging (SWI) and (B) its minimum intensity projection (SWI mIP) of the human brain obtained at 10.5 T using a self-decoupled 16Tx/80Rx head coil.

Discussion:

We achieved similar central SNR gains with different transmitter architectures, indicating that the inclusion of the transmitter as a receiver (regardless of design) is essential for capturing optimal SNR at 10.5T. The demonstrated gains in central SNR led to more fidelity in anatomical (Fig 4) and functional imaging as well as spectroscopic utility deep in the brain at UHF fields strengths. However, since both of our 56 & 64-channel 10.5T receiver inserts [9] as well as the 32-channel 7T insert used by Gosselink [2] utilized partially gapped layouts, we feel in future work it would be important to evaluate if the difference between gapped receiver layouts vs. fully overlapped receivers [10-12] reduces the central SNR gains shown here.

Conclusion:

There are clear advantages of the combination of transmitters with dedicated receiver arrays at UHF; these array combinations support B_1^+ control, improve SNR, and aid in parallel imaging performance [1-5]. Here we shown further advantages (namely in central SNR) of this concept beyond typical 32 and even 64 channels at UHF by utilizing of the transmit array elements as additional receivers. Thus, pointing to a future with UHF systems which can support parallel transmit (8 and 16 Ch. pTx) and upwards of 64 receivers – for example 96 or 128 channels.

Acknowledgements:

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